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A smart guidance navigation robot using petri net, database location, and radio frequency identification

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ABSTRACT

The objective of this research is, to explain a new framework to navigate the movement of the robot towards a target goal. This involves the need for the robot to move from the initial position to 1 out of 30 rooms. Therefore the strategy used involves the combination of the room database stored in the RFID data using the petri net (PN) method to simulate and model the movement of the robot for navigation after which the dynamic behavior of the robot is moving to the desired location was analyzed. The process started from the creation of an environmental map determined by the user followed by modeling through PN and the result was used to produce a marking value which explains and navigates the movement of the robot towards the selected room. The marking value was also used as the database for the robot's movement and later substituted with the RFID to be used as the sensor input in the implementation stage. It was concluded that the robot has the ability to move to the target position according to the database stored in RFID and designed to move forward and turn left and right. For example, it followed the marking value M1 M2 M3M13M12 M11 M10 M9 M8 to Room 1 and M1 M2 M46 M47 to Room 29.

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1. INTRODUCTION

This research was conducted to describe the navigation system for mobile robots assumed to be moving autonomously in man-made environments such as hallways in a building. The main focus is on global and local path planning. The key function of global path planning is to dictate a direction towards a goal at a particular place such as the intersection of two hallways in a building while the local path planning plays a role in moving the robot along walls to avoid obstacles. The navigation system, therefore, requires a mechanism to recognize these places in the building and locating them on a world map to provide course directions to the goal.

There is also a need for the function to generate a free space map in a hallway. Moreover, the two common approaches to global path planning are metric-based and landmark-based navigation [1]. Metric-based navigation relies on metric maps of the environment and this results in navigation plans such as moving forward five meters, turning ninety degrees right, and moving forward another eight meters. Meanwhile, this approach relies on dead-reckoning for position-sensing schemes based on information on the motion of the robot derived from the wheel encoders [2]. These metric data are, however, likely to be corrupted by sensor noise and this navigation method is vulnerable to inaccuracies in position estimates.

This means navigation is one of the important problems needed to be resolved in developing mobile autonomous robot technology towards supporting its mobility. This problem involves several important components starting from the issues of perception which is indicated by the method required by an autonomous robot to obtain certain data from the surrounding environment and be able to interpret them into useful information for the next process. This is, however, closely related to the sensor and recognition problems.

The next problem is localization which is a method or way for an autonomous robot to know its position or existence in an environment it is required to complete a mission or achieve the objectives assigned. Meanwhile, the last problem related to the development of a navigation module in autonomous robots is the problem of cognition and motion control. This is related to the methods applied by the autonomous robots to move towards reaching a destination position required to complete a mission. These are, therefore, associated with the development of computational problem-solving algorithms to determine the steps required to be taken by an autonomous robot from its initial position to its final destination position based on its ability to interact and control its motor components.

Radio frequency identification (RFID) is the wireless non-contact use of radiofrequency waves to transfer data. Tagging items with RFID tags allows users to automatically and uniquely identify and track inventory and assets and the concept has taken the auto-ID technology to the next level by allowing tags to be read without a line of sight with the range observed to be between a few centimeters to several meters depending on the type of the RFID. This technology has come a long way from its first application and this makes it more cost-effective and efficient.

Every RFID system contains at least the following four components, readers, antennas, tags, and cables even though each system varies in terms of type and complexity of the device. RFID tags communicate with readers and antennas via electromagnetic waves in the vicinity with the energy from the waves harnessed by the RFID tag’s antenna used in forming a current which moves towards the center of the tag to energize the integrated circuit (IC). This IC is turned on, modulates the energy with data from its memory banks, and directs a signal back out through the tag’s antenna.

Petri nets (PN) are graphical and mathematical modeling tools applicable to several systems [3]-[6]. They are a promising tool to describe and study the information processing systems characterized as being concurrent, asynchronous, distributed, parallel, nondeterministic, and/or stochastic. Moreover, PN also serve as a graphical tool to provide visual-communication aid which is similar to flow charts, block diagrams, and networks. They also have tokens to simulate the dynamic and concurrent activities of systems.

Many studies have been conducted on mobile robots with only one goal target control as observed with the use of fuzzy logic [7]-[11], particle swarm optimation [12], odometry [13], the need for precise motor rotation constraint, database using RFID for only one goal target [14]-[19], motion robot [20]-[23], navigation gps [24], merging between PN and RFID for navigation with 1 destination and 4 destinations [25]-[27].

The objective of this research is, to explain a new framework to navigate the movement of the robot towards a target goal. This involves the need for the robot to move from the initial position to 1 out of 30 rooms. Therefore the strategy used involves the combination of the room database stored in the RFID data using the PN method to simulate and model the movement of the robot for navigation after which the dynamic behavior of the robot is moving to the desired location was analyzed.

2. PETRI NET FUNDAMENTALS

A PN is a graphical and mathematical tool used in modeling concurrent, asynchronous, distributed, parallel, non-deterministic, and/or stochastic systems. A formal definition of a PN [3] is, therefore, presented in (1).

$$PN=(P, T, I, O, M) \tag{1}$$

a. P={p1, p2, p3 ... pn} is a group of a place with $n \geq 0$.
b. T={t1, t2, t3 ... tm} is a group of a transition with $m \geq 0$.
c. I is mapping input $P \times T \rightarrow \{0, 1\}$ relating to the group of arrow originating from P to T, and the arrow is also called the input.
d. O is mapping output $T \times P \rightarrow \{0, 1\}$ relating to the group of arrow originating from T to P, and the arrow is also called the output.
e. M: P is marking places with the number of token in place.

The movement of the token through the PN represents the dynamical behavior of the system and the position of the token can be changed using the following transition firing rule:

a. A transition t ∈ T is enabled if every input place p ∈ P of t has w (p,t) tokens or more where w(p,t) is the weight of the arc from p to t.
b. An enabled transition t will fire if the event represented by t takes place.
c. When an enabled transition t fires, w (p,t) tokens are removed from every input place p of t and w(t,p) tokens are added to every output place p of t where w(t,p) is the weight of the arc from t to p.

2.1. Modeling of the petri net

In modeling a graph from a PN, there are 4 components involved and they include

a. Place (P) which is represented by a circle,
b. Transition (T) which is represented by a rectangle or bar,
c. Token which is represented by a dot, and
d. Arrow which is the connection between place and transition.

2.2. Benefits of petri net

PN is useful to model a system with the following characteristics as:

a. Conflict, conflict modeling in Figure 1 (a) is very suitable when actions like selecting a path need to be defined such as going straight, turning left, or turning right. It is, therefore, possible to implement the sequence of movement of the PN model step by step to achieve the goal.
b. Sequence, in Figure 1 (b), transition t2 can fire only after the firing of t1. This imposes the precedence constraint “t2 after t1”. Such precedence constraints are typical of the execution of the parts in a dynamic system. Also, this PN construct models the causal relationship among activities.

(a) (b)

Figure 1. Modeling for PN, (a) conflict, (b) sequence

2.3. To run a petri net

A PN causes changes to the previous marking and it is executed by firing at a possible marking. Meanwhile, a transition is enabled when each input place has a minimum of one token and the firing is marked by the movement of the token from place input to place output for the transition. This is usually followed by the movement of the token through an arrow from one place to another.

It has been previously shown that the dynamic direct effect of PN is described by the changes in its stepping and markings when advancement fires after the data states are checked. Even more formally, an advancement tj is enabled in checking Mlast if Mlast (pi)=I (pi, tj), and Mnew is reachable from Mlast according to the following condition.

$$Mnew=Mlast + (O-I)\ Tfiring \quad (2)$$

A change in tj fires produces exactly another checking, Mnew, which occurs by removing I(pi, tj) tokens from all of its information and replace them with O(pi, tj) tokens in all the yield places.

3. PROPOSED APPROACH

The combination of PN and RFID is very possible due to the potentials of RFID to function as navigation for robot movement using the place, transition, and token models. The following flowchart, however, explains the process of filling-in the room data based on the RFID after the PN model has been formed. All the activities of the robot starts from the home position to the desired position, for example, the movement towards room 1 requires the robot moves from the home position to the target goal which is room 1. Figure 2 explains how the conversion process from the landmark environment into the PN model. After obtaining the place, transition, arrow, and token direction models will be generated the marking values, which will be inputted into RFID as a mobile robot navigation database. The desire of the mobile robot will be triggered using RFID. To get to the desired room.

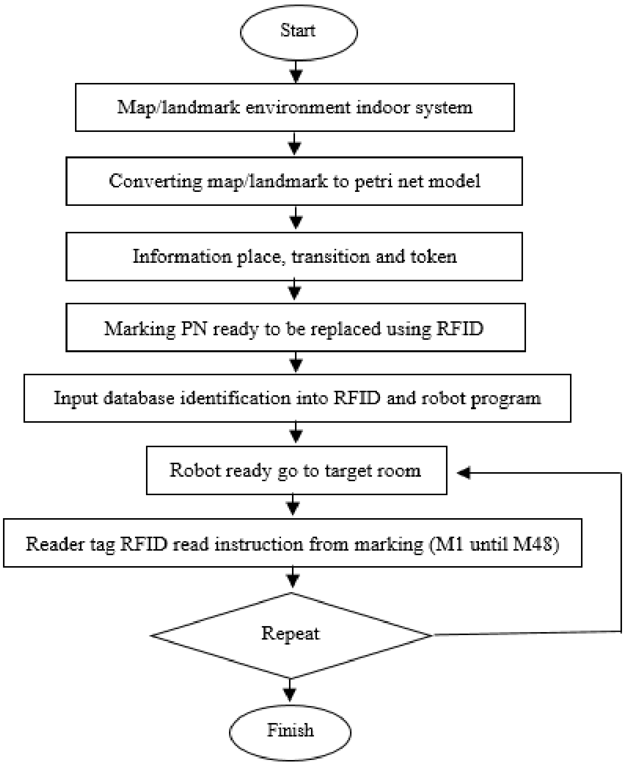


Figure 2. Process of converting map/landmark and input database into RFID with PN

3.1. Worked example

Figure 3 explains the movement of a robot from the home position to the target room out of 30 rooms and this landmark image was later converted into a PN model. The robot is shown in the image to be available in the home position and to later move to 30 spaces precisely after which the landmark map was converted to a PN model. Figure 4 describes the results of the landmark image conversion to show the natural conversion model of robot movement after which this image was used to comprehensively explain each place and transition. The token in place 1 (P1) indicates the beginning of the movement starting from the home position.

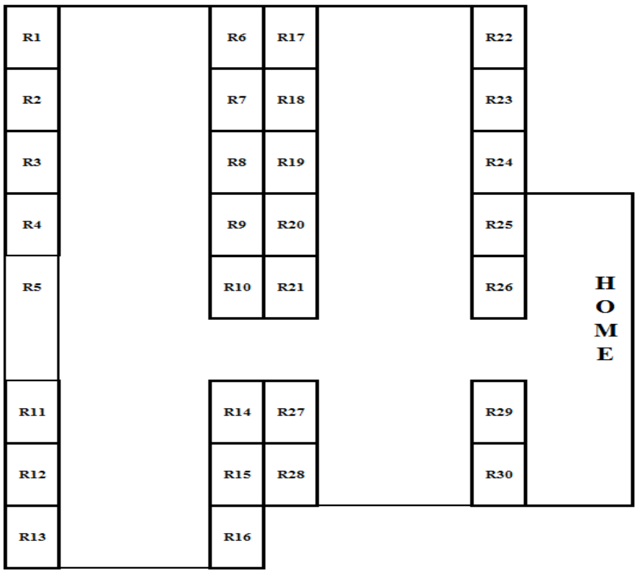


Figure 3. Landmark

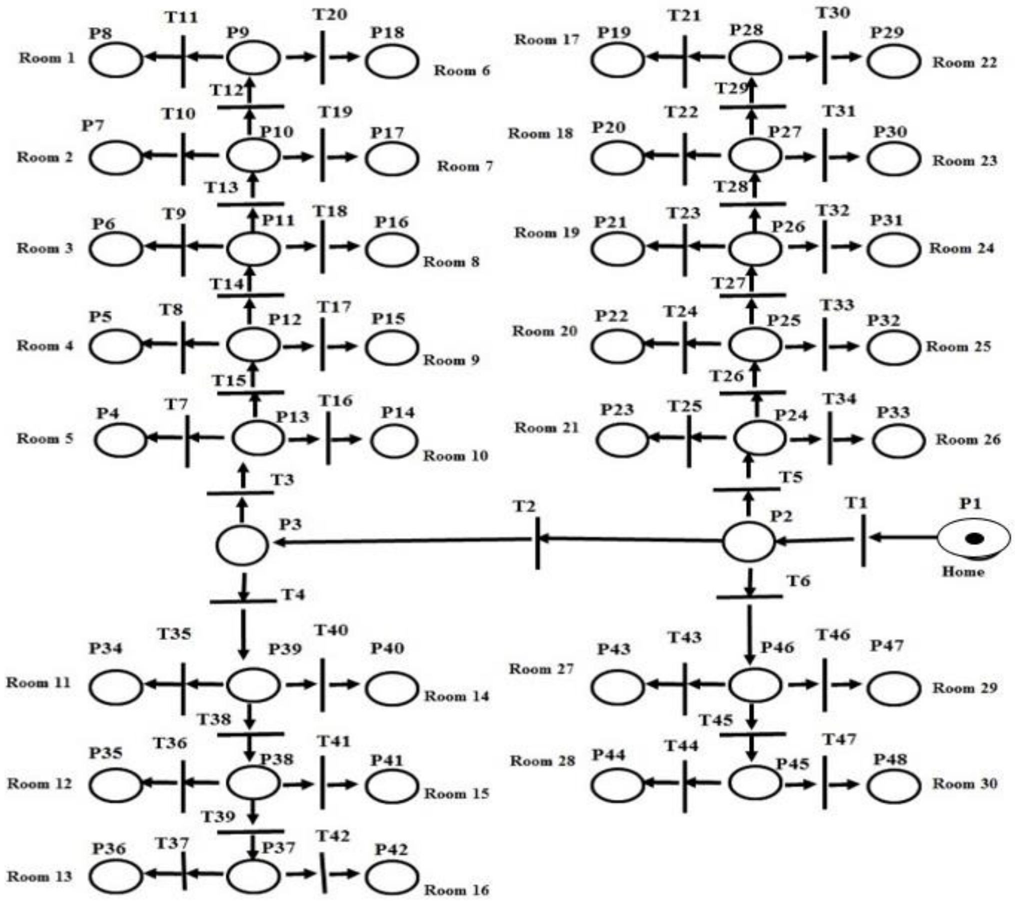


Figure 4. PN model from Figure 3

Table 1 shows the place value and the marking value used in explaining the position of the robot while the transition value was used to describe its motion. The three main movements observed were straight, turning left, and turning right. The Table 2 shows each room to be addressed as a database when moving to a certain room starting with marking M1 and total rfid usage is 48 RFID for marking and 30 RFID for database so total 78 rfid for models like this.

Table 1. The place, transition, and marking models

Place	Marking	Position Robot	Transit ion	Move Robot	Place	Marking	Position Robot	Transi tion	Move Robot
P1	M1	Home position	T1	Straight	P25	M25	Choose turn left/right/straight	T25	Turn left
P2	M2	Choose turn left/right/strai ght	T2	Straight	P26	M26	Choose turn left/right/straight	T26	Straight
P3	M3	Choose turn left/right	T3	Turn right	P27	M27	Choose turn left/right/straight	T27	Straight
P4	M4	Robot at room 5	T4	Turn left	P28	M28	Choose turn left/right/straight	T28	Straight
P5	M5	Robot at room 4	T5	Turn right	P29	M29	Robot at room 22	T29	Straight
P6	M6	Robot at room 3	T6	Turn left	P30	M30	Robot at room 23	T30	Turn right
P7	M7	Robot at room 2	T7	Turn left	P31	M31	Robot at room 24	T31	Turn right
P8	M8	Robot at room 1	T8	Turn left	P32	M32	Robot at room 25	T32	Turn right
P9	M9	Choose turn left/right	T9	Turn left	P33	M33	Robot at room 26	T33	Turn right

Table 1. The place, transition, and marking models (*continue*)

Place	Marking	Position Robot	Transition	Move Robot	Place	Marking	Position Robot	Transition	Move Robot
P10	M10	Choose turn left/right/straight	T10	Turn left	P34	M34	Robot at room 11	T34	Turn right
P11	M11	Choose turn left/right/straight	T11	Turn left	P35	M35	Robot at room 12	T35	Turn right
P12	M12	Choose turn left/right/straight	T12	Straight	P36	M36	Robot at room 13	T36	Turn right
P13	M13	Choose turn left/right/straight	T13	Straight	P37	M37	Choose turn left/right	T37	Turn right
P14	M14	Robot at room 10	T14	Straight	P38	M38	Choose turn left/right/straight	T38	Straight
P15	M15	Robot at room 9	T15	Straight	P39	M39	Choose turn left/right/straight	T39	Straight
P16	M16	Robot at room 8	T16	Turn right	P40	M40	Robot at room 14	T40	Turn left
P17	M17	Robot at room 7	T17	Turn right	P41	M41	Robot at room 15	T41	Turn left
P18	M18	Robot at room 6	T18	Turn right	P42	M42	Robot at room 16	T42	Turn left
P19	M19	Robot at room 5	T19	Turn right	P43	M43	Robot at room 27	T43	Turn right
P20	M20	Robot at room 17	T20	Turn right	P44	M44	Robot at room 28	T44	Turn right
P21	M21	Robot at room 18	T21	Turn left	P45	M45	Choose turn left/right	T45	Straight
P22	M22	Robot at room 19	T22	Turn left	P46	M46	Choose turn left/right/straight	T46	Turn left
P23	M23	Robot at room 20	T23	Turn left	P47	M47	Robot at room 29	T47	Turn left
P24	M24	Choose turn left/right/straight	T24	Turn left	P48	M48	Robot at room 30	-	-

Table 2. Database based on target room destination

RFID	Target Room	Database Navigation	RFID	Target Room	Database Navigation
Tag 1	R1	M1 M2 M3 M13 M12 M11 M10 M9 M8	Tag 16	R16	M1 M2 M3 M39 M38 M37 M42
Tag 2	R2	M1 M2 M3 M13 M12 M11 M10 M7	Tag 17	R17	M1 M2 M24 M25 M26 M27 M28 M19
Tag 3	R3	M1 M2 M3 M13 M12 M11 M6	Tag 18	R18	M1 M2 M24 M25 M26 M27 M20
Tag 4	R4	M1 M2 M3 M13 12 M5	Tag 19	R19	M1 M2 M24 M25 M26 M21
Tag 5	R5	M1 M2 M3 M13 M4	Tag 20	R20	M1 M2 M24 M25 M22
Tag 6	R6	M1 M2 M3 M13 M12 M11 M10 M9 M18	Tag 21	R21	M1 M2 M24 M23
Tag 7	R7	M1 M2 M3 M13 M12 M11 M10 M17	Tag 22	R22	M1 M2 M24 M25 M26 M27 M28 M29
Tag 8	R8	M1 M2 M3 M13 M12 M11 M16	Tag 23	R23	M1 M2 M24 M25 M26 M27 M30
Tag 9	R9	M1 M2 M3 M13 M12 M15	Tag 24	R24	M1 M2 M24 M25 M26 M31
Tag 10	R10	M1 M2 M3 M13 M14	Tag 25	R25	M1 M2 M24 M25 M32
Tag 11	R11	M1 M2 M3 M39 M34	Tag 26	R26	M1 M2 M24 M33
Tag 12	R12	M1 M2 M3 M39 M38 M35	Tag 27	R27	M1 M2 M46 M43
Tag 13	R13	M1 M2 M3 M39 M38 M37 M36	Tag 28	R28	M1 M2 M46 M45 M44
Tag 14	R14	M1 M2 M3 M39 M40	Tag 29	R29	M1 M2 M46 M47
Tag 15	R15	M1 M2 M3 M39 M38 M41	Tag 30	R30	M1 M2 M46 M45 M48

4. RESULTS

Figure 5 indicates the laying of marking position starting from the starting position of home position M1 until the final position of room 30 M48. Figure 6 (a) shows the robot moved from the home position to room 1 and this required filling the database with a program to follow the marking which contains the straight movement, turning left, and turning right as indicated by M1 M2 M3 M13 M12 M11 M10 M9 M8. Figure 6 (b) The robot also moved from the home position to room 29 and this required the database was filled with a program to follow the marking which contains straight movement, turning left, and turning right as indicated by M1 M2 M46 M47. The robot moves to the room based on the PN and the RFID database and obtains the navigation direction from the RFID. Figure 7 explaining the test room robot moves into the room based on PN and RFID databases, the robot moves to the room based on the PN and the RFID database and obtains the navigation directly from the RFID.

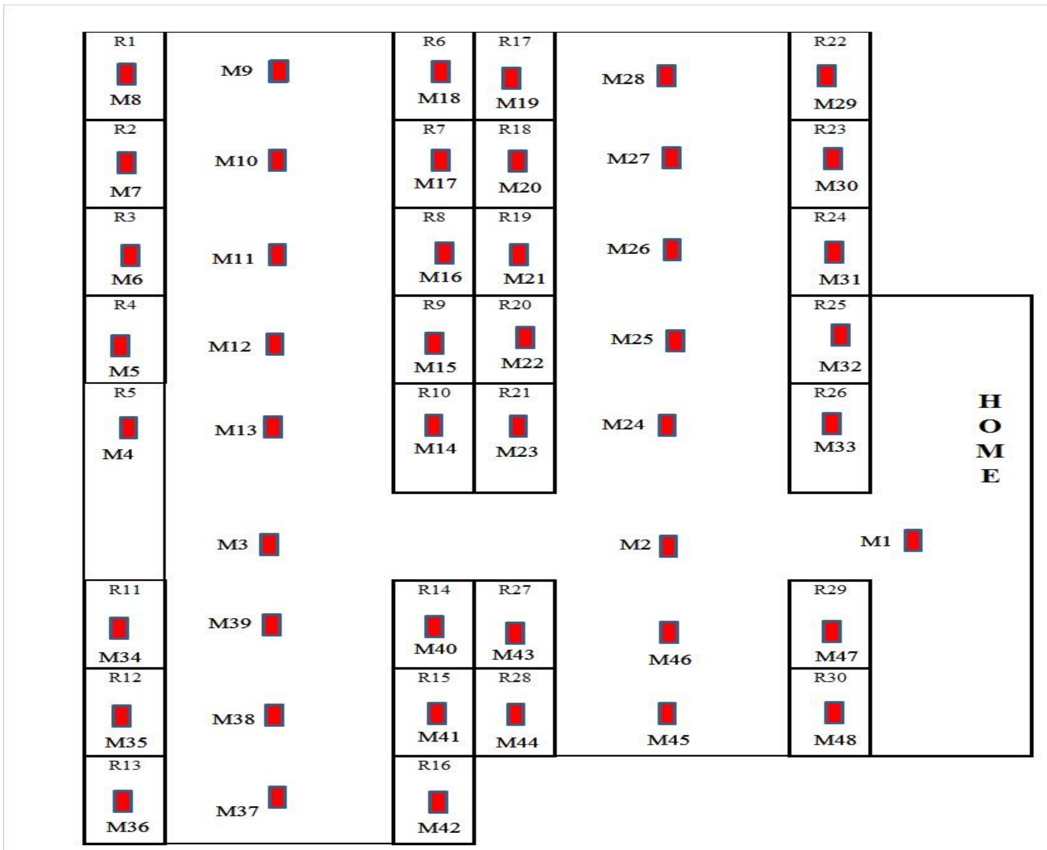
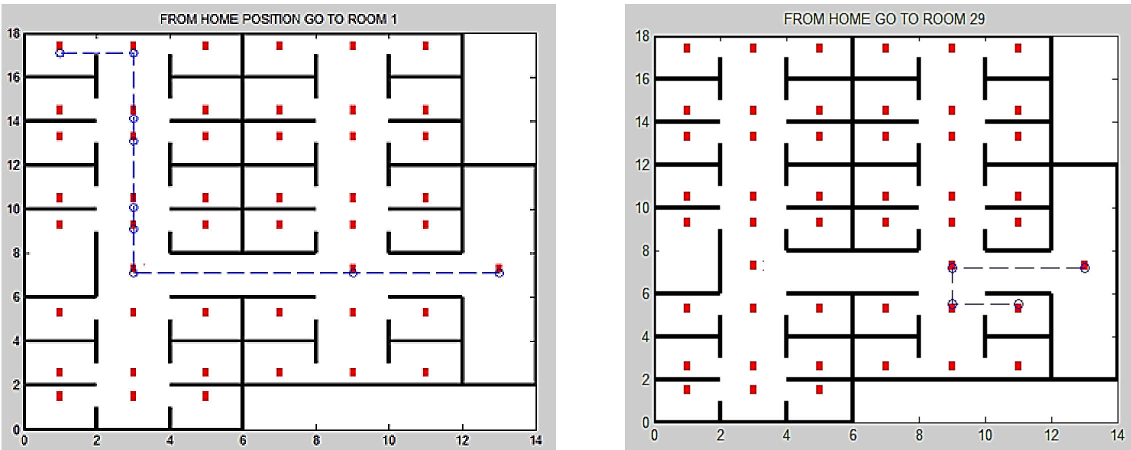


Figure 5. Marking position (RFID) for guidance navigation



(a) (b)

Figure 6. Simulation of mobile robot movements; (a) from the home position to room 1 and, (b) from the home position to room 29

Figure 7. The map environment

5. CONCLUSION

The mobile robot movement using the PN was successfully simulated by converting the landmark/map environment into a PN model, using simulations from the model to describe the place, transition, token, and marking after which the robot was made to move based on the model database in the form of the marking value which was used to navigate the robot to move straight, turn right, and turn left. The marking was later replaced with RFID with the design that the robot movement will change when the RFID is detected.

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